U.S. Monetary Policy Surprises and Currency Futures Markets: A New Look

Tao Wang
Queens College and the Graduate School of CUNY

Jian Yang*
University of Colorado Denver

Marc W. Simpson
University of Northern Illinois

March 2008 (Final Version)

Intraday currency futures prices react to both surprises in the federal funds target rate (the target factor) and surprises in the anticipated future direction of Federal Reserve monetary policy (the path factor) in similar magnitude, and the reaction is short-lived. Dollar-denominated currency futures prices drop significantly in response to positive surprises (i.e., unexpected increases) in the target and path factors, but have generally little response to negative surprises. A monetary policy tightening during expansionary periods leads to an appreciation of the domestic currency, while a monetary policy loosening during recessionary periods tends to have no significant impact.

Keywords: monetary policy, FOMC statements, asymmetry, currency futures

JEL classification: G14

**Corresponding author*: The Business School, PO Box 173364, University of Colorado Denver Denver, CO 80217-3364. Email: Jian.Yang@cudenver.edu. Tel: (303) 556-5852; Fax: (303) 556-5899.

We thank Refet Gurkaynak for kindly providing some data used in this study. The earlier versions of the paper were presented at 2006 Eastern Finance Association, 2006 Western Economics Association, and 2006 Financial Management Association annual meetings. We thank session participants, the editor (Cynthia Campbell), and particularly the anonymous referee for very extensive comments. Wang and Yang acknowledges financial support from the PSC-CUNY research grant and the UC Denver Faculty Research & Scholarship Completion Fund, respectively.

1. Introduction

The conduct of a country's monetary policy and the determination of the rate of exchange of the country's currency are inextricably linked. While various theories assert a link between monetary policy and exchange rates, there is disagreement regarding the direction and the nature of the monetary policy impact on exchange rates (Almeida, Goodhart and Payne, 1998, p.384; Bonser-Neal, Roley and Sellon, 2000; Lobo, Darrat and Ramchander, 2006). Accordingly, as pointed out in Eichenbaum and Evans (1995) and Andersen, Bollerslev, Diebold and Vega. (2003), the empirical evidence on the role of monetary policy in exchange rate determination is mixed, at best. Some influential studies even suggest a disconnect between exchange rates and economic fundamentals (including monetary fundamentals). Using monthly data, some earlier studies provide favorable evidence of a link between monetary policy and the exchange rates (e.g., Eichenbaum and Evans, 1995). However, using monthly data to estimate the monetary policy impact on asset markets can be problematic because of the endogeneity problem and omitted variable biases (Bernanke and Kuttner, 2005).[1] To overcome these problems, recent studies have used high frequency intraday data to investigate the effect of monetary policy announcements on currency markets. These studies, however, typically use the federal funds rate as the sole indicator of U.S. monetary policy (e.g., Andersen,, Bollerslev, Diebold and Vega., 2003; Faust, Wang and Wright, 2007).[2]

Motivated by the fact that Federal Reserve monetary policy decision-making has moved significantly in the direction of greater transparency over the past decade—which should improve communication with market participants and shape investors' expectations—researchers

[1] Even at the daily frequency, Rudebusch (1998) notes that simultaneity biases can still be a potential problem because the U.S. Federal Open Market Committee (FOMC), during a time period before 1994, often changed the federal funds target rate merely hours after the unemployment report was released by the Bureau of Labor Statistics.
[2] There is also evidence that it is only unanticipated changes in the federal funds rate that affect asset markets, while anticipated changes in the federal funds rate have little effect (Rigobon and Sack, 2004).

have recently looked beyond changes in the current federal funds rate target as the only monetary policy indicator. In particular, since February 1994, the Federal Open Market Committee (FOMC) began releasing statements that accompanied changes in the federal funds rate target. These statements provide additional information on the stance of monetary policy beyond the information provided by the federal funds rate target alone. Additionally, literature on U.S. central bank communication is emerging. Bernanke, Reinhart and Sack (2004) found that clear communication in the FOMC statements can help increase the near-term predictability of FOMC federal funds rate decisions, which is also supported by Kohn and Sack (2003) and Pakko (2005). Gurkaynak, Sack and Swanson (2005) decomposed the information from the FOMC meetings into two factors, the target factor (i.e., the surprises in the federal funds rate target) and the path factor (i.e., the surprises in the future direction of the federal reserve monetary policy independent of changes in the current funds rate target). They report that both factors have important, though differing, effects on Treasury bond yields while only surprises in the current federal funds rate target has an impact on the S&P 500 index. Wang, Yang and Wu (2006) provide the additional evidence for the importance of both factors on equity ETF markets after allowance for various types of asymmetry.

In this study, we use high frequency currency futures price data to measure the impact of U.S. monetary policy news on currency markets.[3] Our study extends previous research in the following important ways. First, this paper is the first to explore and report the (intraday) impact on currency markets of unexpected changes in the anticipated path of Federal Reserve monetary

[3] The monetary policy surprises of other major countries (e.g., Japan, Eurozone/Germany, and UK) might also have some impacts on the currency market movements. Unfortunately, such data are not available. The existing literature (Almeida, Goodhart and Payne, 1998; Andersen, Bollerslev, Diebold and Vega, 2003) has only explored the German macroeconomic (including monetary) news, and finds their limited impacts on U.S./DM exchange rates. Andersen, Bollerslev, Diebold and Vega (2003) argue that the relatively small impacts of German macroeconomic news (compared to U.S. macroeconomic news) could be due to their uncertain release times or relatively large pre-announcement leakage.

policy, as implied in FOMC statements (or by the FOMC decisions in early years). While recent works (e.g., Bernanke, Reinhart and Sack, 2004; Gurkaynak, Sack and Swanson, 2005; Pakko, 2005; Wongswan, 2005; Hausman and Wongswan, 2006; Wang, Yang and Wu, 2006) have explored the potential impact of the information contained in the FOMC statements on equity and bond markets, none of them has examined currency markets.[4] As pointed out by Andersen, Bollerslev, Diebold and Vega (2003), the focus on currency markets as opposed to stock or bond markets is an important differentiating feature because in literature there is notoriously little evidence of an impact of economic fundamentals on exchange rates. Monetary fundamentals are often considered to be the most important type of economic fundamentals in driving currency market movements, as suggested by the monetary approach to exchange rate determination. Almeida, Goodhart and Payne (1998, p. 406) further argue that the most sensible explanation of currency market reactions to macroeconomic news lies in market participants' anticipation of how the monetary authority will react to the news. Thus, the focus of future research should be on exchange rate responses to unexpected short-term interest rate changes using high frequency data.

Further extending earlier works (e.g., Andersen, Bollerslev, Diebold and Vega, 2003; Faust, Wang and Wright, 2007), this new kind of monetary policy news effect is found to be as important on currency futures markets as that of the unexpected component of federal funds rate target changes. The finding is even more significant in light of the very limited effectiveness of European Central Bank statements on (the conditional mean of) the Euro/Dollar exchange rate

[4] Perhaps the only exception is a subsequent study by Hausman and Wongswan (2006), which comprehensively investigates the response of global asset prices (including many exchange rates) to FOMC announcements. The authors conclude that different asset classes can respond to monetary policy surprises in different ways. Their study, however, substantially differs from ours, in that the authors use daily rather than high frequency intraday data and do not explore the potential asymmetry pattern. Perceivably due to these differences, Hausman and Wongswan (2006) find that exchange rates respond mainly to the path surprise, while we report that exchange rates respond to both the target and path surprises.

(Jansen and De Haan, 2005) and the small impact of FOMC statements on U.S. and global equity markets (Gurkaynak, Sack and Swanson, 2005; Wongswan, 2005).

Second, this study is the first to comprehensively examine the asymmetry in the response of currency markets to monetary policy using high frequency data. As vigorously argued in Almeida, Goodhart and Payne (1998), the use of high-frequency data is critical to detecting discernible effects of economic news on exchange rates, which could otherwise be masked by subsequent exchange rate fluctuations (also see Wongswan, 2006, for a similar point in the context of equity market prices). Prior research typically does not consider asymmetric effects of monetary policy on currency markets, either. Andersen, Bollerslev, Diebold and Vega (2003) and Lobo, Darrat and Ramchander (2006) are two notable exceptions. Specifically, Andersen, Bollerslev, Diebold and Vega (2003) show the asymmetric high frequency response of currency markets with regard to the sign of macroeconomic news in general (with emphasis on several real activities news), but not monetary policy news specifically. Lobo, Darrat and Ramchander (2006) employ daily data and examine whether the magnitude of the currency markets' response depends on the direction of the rate movement (i.e., contractionary versus expansionary monetary policy).[5] By contrast, we examine several (rather than one) types of potential asymmetries associated with the sign of the surprises, the size of the surprises, the direction of the rate movement, and the stage of the business cycle. The use of high frequency data over a 15-year period, which is much longer than any previous study, clearly facilitates the meaningful investigation of these types of asymmetries. Furthermore, all of the potential asymmetric effects on currency markets are, for the first time, studied within the context of a two-factor (rather than

[5] Different from Lobo, Darrat and Ramchander (2006) but similar to Andersen, Bollerslev, Diebold and Vega (2003), our use of a small window of five minutes after the FOMC rate changes and announcements can also greatly reduce the probability that the FOMC decisions, and more importantly, the detected currency market movements are influenced by other macroeconomic news. Also see Gurkaynak, Sack and Swanson (2005).

one-factor) empirical specification, which allows for a potentially asymmetric response to the information contained in the FOMC statements. The study also differs from Bernanke, Reinhart and Sack (2004), Gurkaynak, Sack and Swanson (2005), and Wongswan (2005) since we do not assume a symmetrical relation between the asset price response and this second factor.

The rest of the paper is organized as follows: section 2 discusses some pertinent literature, section 3 describes the data, section 4 presents the methodology, section 5 discusses the results, and the last section contains concluding remarks.

2. Asymmetric responses to monetary policy surprises

Most previous investigations into the linkages between monetary policy and exchange rate formation have implicitly assumed that foreign exchange markets respond symmetrically to changes in monetary policy. Yet, studies of other financial markets would tend to suggest the imprudence of assuming symmetrical responses to news.

Jensen, Mercer and Johnson (1996) showed that the returns on stocks and bonds vary asymmetrically depending on the prevailing state of the monetary policy. Their study was perhaps the first to argue that the monetary environment could have as important an influence on asset (i.e., stock and bond) returns as the stage of the business cycle. Andersen, Bollerslev, Diebold and Vega (2003, p. 50) suggest that future research should examine the potentially time-varying pattern of the exchange rate response to macroeconomic news over the business cycle. Whether they focus on monetary policy or on the business cycle, many researchers postulate that investors view the economy as following a two-state regime switching process (see, for example, Barberis, Shleifer and Vishny, 1998; Veronesi, 1999). Within such models, agents respond asymmetrically to news, depending on the prevailing regime. Specifically, these models imply that bad news in good times should have an unusually large impact, a view that is also shared among practitioners (Conrad, Cornell and Landsman, 2002). Bad news in a "bad" regime elicits little response because it is mostly anticipated; however, bad news in a "good" regime is unanticipated and therefore leads to a significant reaction. Andersen, Bollerslev, Diebold and Vega (2003) examined the effect of bad news in good times on the currency market and found support of the Veronesi model (1999) that bad news in good times indeed has an unusually large impact. Lobo, Darrat and Ramchander (2006) examined whether tightening and easing actions of the Federal Reserve policy symmetrically affect currency markets. They found that surprises associated with tightening have a larger effect compared with monetary easing for the Pound, Mark, and the Canadian dollar; whereas the opposite is true for the Japanese Yen. They conjectured that one reason for the asymmetry is due to the reactions of foreign central banks to Fed actions although they did not empirically test the hypothesis.

If agents react asymmetrically to news, it could be a serious error to measure the impact of such news on financial markets implicitly assuming symmetry in the reactions. For example, consider a situation in which the relation between two variables, *y* and *x*, varies depending on the values of *x*, so that for $x > 0$, $y_t = \alpha + x_t \beta_+$ and for $x \leq 0$, $y_t = \alpha + x_t \beta_-$. If $\beta_+ \neq \beta_-$, then the asymmetry in the slope parameter would mean that estimating the relation via OLS in the following regression could lead to spurious inferences:

$$y_t = a + bx_t + \varepsilon_t \qquad (1)$$

For example, consider a case where the true parameters are as follows: $\alpha = 0$, $\beta_+ = 1$, and $\beta_- = -1$. In this case, a scatter diagram of the relation between *x* and *y* would be V-shaped. Furthermore, it is very likely that the *b* coefficient from equation (1) would not be statistically different than zero, while the estimated value of b would vary between 1 and -1 depending on the relative variance of the sample when x is negative versus when it is positive.[6]

Hence, in situations where one might suspect that the relation between two variables is asymmetrical, a better approach would be to adapt the linear regression model as follows:

$$y_t = c + b_+ x_t^+ + b_- x_t^- + \xi_t \tag{2}$$

where x_t^+ is a vector containing the value of x when the value is positive and zeros otherwise, and x_t^- is a vector containing the value of x when the value is negative and zeros otherwise, and b_+ and b_- are the coefficients to be estimated. See Johnston (1972, p. 157-159) for a discussion of the econometric implications of symmetrical restrictions in regression analysis and Haynes (1983) and Simpson, Ramchander and Webb (2007) for applications of the technique illustrated in equation (2).

3. Data

The data used include the prices of foreign exchange futures contracts (Euro, Deutsche Mark, Japanese Yen, British Pound) and the prices of federal funds and the Eurodollar interest-rate futures contracts traded on the Chicago Board of Trade and the Chicago Mercantile Exchange. The daily transaction record extends from 8:20 EST until 15:00 EST for the Deutsche Mark, Euro, Japanese Yen, British Pound, and federal funds futures contracts.[7] The futures prices are quoted in dollars per foreign currency except for the Yen future that is quoted in

[6] As discussed in Johnston (1972), the coefficient estimate of b in equation (1) would be a weighted average of the coefficient estimates of b_+ and b_- from equation (2), where the weight on the coefficient estimate of b_+ would be: [Var(x^+)+Cov(x^+, x^-)]/Var(x), and the weight on the coefficient estimate of b_- would be: [Var(x^-)+Cov(x^+, x^-)]/Var(x).

[7] During the later part of our sample period, there is electronic trading after 15:00 EST; however, we only use the price records during the open-cry period that is from 8:20 EST until 15:00 EST due to data availability.

dollars per 100 Yen. Given their contract size, one basis point change is equivalent to U.S. $12.5, U.S. $12.5, U.S. $6.25, U.S. $12.5 changes for the Euro, Mark, Pound, and the Yen futures contracts, respectively. All of the data are intraday tick-by-tick observations, and we sample them at five-minute intervals for our analysis; however, for the interest rate changes we only make use of the observations from nearby interest rate futures contracts. The sample period for the monetary policy incidences is from February 1990 to December 2004, a total of 136 observations.[8] For the Euro futures, we use the Deutsche Mark data from February 8, 1990 to June 30, 1999 and the Euro after July 1, 1999. Andersen, Bollerslev, Diebold and Vega (2007) and Lobo, Darrat and Ramchander (2006) used the same approach to merge the German mark and the Euro series.

3.1 Monetary policy incidence

In addition to changes in the federal funds rate target, we also examine the impact of "non-standard monetary policy" on foreign exchange futures contracts. The potential impact of Federal Open Market Committee (FOMC) statements has captured much attention recently. Much of this shift in focus can be traced to changes in the manner in which policymakers disseminate information. Over the past decade, there has been a movement on the part of the FOMC towards greater transparency.

From January 1989 to December 1993, the FOMC typically relied on open market operations to signal shifts in monetary policy without post-meeting announcements. FOMC target rate decisions became effective the day after the decisions were made. Therefore, market participants had to rely on market trading information to interpret monetary policy changes. From February 1994 to November 1998, however, the FOMC began releasing statements that

[8] Three major policy incidences during our sample are not used due to the non-trading-hour restrictions: the discount rate change at 15:30 EST on December 18, 1990, the FOMC inter-meeting announcement at 15:15 EST on October 15, 1998, and the FOMC inter-meeting announcement at 8:20 EST on September 17, 2001.

accompanied changes in the federal funds target rate. These statements explained the rationale for the policy action, but they did not have any explicit assessment of the risk going forward. At the December 1998 meeting, the FOMC made a decision that in addition to releasing statements accompanying policy actions, it would release statements whenever it wanted to communicate to the public a major shift in its views about the balance of risks or the likely direction of future policy. The first such statement was released at the May 1999 FOMC meeting. The statement announced a "policy tilt" toward tightening. In January 2000, the FOMC announced that a statement regarding the "balance of risks" faced by the economy would be released after every FOMC meeting. The balance-of-risks assessment would be linked to the FOMC's macroeconomic objectives rather than to the near-term direction of monetary policy. Particularly, the statement would indicate whether the risk for the economy over the "foreseeable future" was weighted toward "economic weakness" or "heightened inflation pressures," or if the risk was balanced.

Therefore, after February 1994, FOMC statements were issued occasionally, and after May 1999, FOMC statements were issued after every meeting, with these latter statements including information about the future direction of the monetary policy. However, the argument can also be made that even on the FOMC meeting date when no FOMC statement was issued, the decision on the target rate itself could potentially affect the market expectation on future monetary policy changes.

3.2 Monetary policy factors

A number of studies have examined the effect of changes in monetary policy on different asset markets. Most of the previous studies use a one-factor empirical specification, which focuses on the impact of the federal funds target rate surprise. Kuttner (2001) proposed to calculate the monetary policy surprise based on the change in the federal funds futures rate, which has been widely used in the literature. Specifically, the unexpected component of the federal fund rate change, denoted as f, is calculated as follows:

$$f = \frac{D}{D-d} \Delta Fundrate \,. \tag{3}$$

where D is the total number of days in the month, d is the day of the month of the FOMC decision, and $\Delta Fundrate$ is the change in the futures rate on the day of the policy decision. Kuttner (2001) used daily federal funds futures prices. In contrast, in this paper, intraday federal funds futures data are used to calculate the unexpected federal funds rate target changes. That is, policy surprises are computed by taking differences between the federal funds futures rate 10 minutes prior to the monetary policy announcement and 20 minutes after the announcement, and then an adjustment is made based on equation (3).

Following Gurkaynak, Sack and Swanson (2005), we use a two-factor empirical specification to examine the effect of potential information contained in the FOMC decisions. The two factors, the target and path factors, are constructed as follows (see Gurkaynak, Sack and Swanson, 2005, for more details). We take the changes in five interest rate futures contracts in the thirty-minute window around the FOMC announcement to create the matrix X. The first two columns in X are the changes in the current-month and three-month-ahead federal funds futures, with a scaling adjustment to account for the timing of FOMC meetings as mentioned above. The next three columns in X are the changes in prices of the second, third, and fourth Eurodollar futures contracts, which have 1.5, 2.5 and 3.5 quarters to expiration on average. After normalizing each column of X to have zero mean and unit variance, we can extract the two principal components. The two factors Z_1 and Z_2 are made orthogonal to each other. Z_1 is normalized so that it mirrors the above-mentioned federal fund futures surprise

$TS_t = \frac{D}{D-d}(ff_{t+20} - ff_{t-10})$ one-for-one, and Z_2 is scaled so that it has the same magnitude effect on the year-ahead eurodollar futures rate as Z_1 has on that rate (about 53 basis points).[9] According to the decomposition, the target factor measures the market's surprise regarding a change in the FOMC's current federal funds target rate. The path factor represents the surprise in the FOMC's direction of future policy as reflected in the wording in the FOMC statements.

4. Methodology

Most studies on news announcements and high frequency data tend to use simple OLS to study the impact of news announcement on returns or volatilities. In this paper, we examine the impact of monetary policy announcements on currency markets using the seemingly unrelated regression (SUR) approach. The justification for the use of the method is straightforward. Even though the OLS estimator would be unbiased and consistent in the high frequency setting, SUR would be necessary for cross-equation hypothesis testing and could improve efficiency due to correlated errors across different currencies.

We first consider the following one-factor empirical specification widely used in the literature:

$$y_{i,t} = \alpha_0 + \beta_i f_t + \theta_i S\&P^{net\ FOMC} + \varepsilon_{fi,t} \qquad (4)$$

and the corresponding two-factor empirical specification is specified as follows:

$$y_{i,t} = \alpha_1 + \gamma_i z_{1,t} + \lambda_i z_{2,t} + \theta_i S\&P^{net\ FOMC} + \varepsilon_{zi,t} \qquad (5)$$

where y_t represents log changes in the currency futures prices, the f_t is the unanticipated component of the change in the federal funds rates by taking the differences between the federal

[9] The target factor is very closely correlated (0.95) with the scaled changes in the federal funds futures prices that Kuttner (2001) used to measure "surprises in the Fed Fund rate." Bernanke, Reinhart and Sack (2004) confirmed that the path factor accurately measures the expected four-quarter-ahead Eurodollar future rates changes due to the monetary policy changes.

funds futures rate 10 minutes prior to the monetary policy announcement and 20 minutes after the announcement and then an adjustment is made according to equation (3), z_1 is the target factor, and z_2 is the path factor for monetary policy as computed in Gurkaynak, Sack and Swanson (2005).[10] These models are empirical in nature rather than directly theoretically motivated.

To control for the potential endogeneity problem due to other shocks that might affect the foreign exchange futures and other assets simultaneously, we add another variable in our regression, $S\&P^{netFOMC}$. We first run the regression of the five-minute S&P500 futures return (immediately after the FOMC decision) on the target and path factors, and obtain the estimated residual that is taken as $S\&P^{netFOMC}$. Lobo, Darrat and Ramchander (2006) used the same approach to control for the impact of other possible news events. Wongswan (2005, 2006) also used a similar approach to control for the possible impact from other news in his analysis of monetary policy or macroeconomic announcements on global equity markets.

Below, we further examine the impact of the monetary policy changes on the five-minute returns by studying the asymmetry of the impact of monetary policy announcements.

4.1 Sign response

One possibility of asymmetry is that the magnitude of the currency market's response depends on the sign of monetary policy surprises. The sign effect of exchange rate response to macroeconomic news has been reported for the first time in Andersen, Bollerslev, Diebold and

[10] As pointed out by the referee, because the target and path surprises are the first two principal components from five interest rate futures, and $S\&P^{netFOMC}$ is the residual from a regression of the S&P500 futures return on the two factors, we might need to account for the possible generated regressor problem. To address this issue, following Wongswan (2005) and Hausman and Wongswan (2006), we compute standard errors of coefficient estimates using sampling-with-replacement bootstrapping with 1,000 repetitions. Similar to Wongswan (2005), the results are qualitatively similar to those reported here based on White (1980)'s robust standard errors. Hausman and Wongswan (2006) also show that the results are quite similar using some alternative proxies of the path factor.

Vega (2003, footnote 23, specifically). To investigate this possibility, we estimate the following one-factor and two-factor empirical specifications using SUR:

$$y_{i,t} = \alpha_0 + \beta_i^+ f_t^+ + \beta_i^- f_t^- + \theta_i S\,\&\,P^{net\ FOMC} + \varepsilon_{fi,t} \tag{6}$$

$$y_{i,t} = \alpha_1 + \gamma_i^+ z_{1,t}^+ + \gamma_i^- z_{1,t}^- + \lambda_i^+ z_{2,t}^+ + \lambda_i^- z_{2,t}^- + \theta_i S\,\&\,P^{net\ FOMC} + \varepsilon_{zi,t} \tag{7}$$

where f_t^+ is a vector that takes on the value of the positive surprise (i.e., unexpected increase) in the federal funds rate and a zero otherwise; f_t^- is a vector that takes on the negative surprise (i.e., unexpected decrease) in the federal funds rate and a zero otherwise; $z_{1,t}^+$ (or $z_{2,t}^+$) is a vector that takes on the positive surprise in the target factor (or path factor) and a zero otherwise; $z_{1,t}^-$ (or $z_{2,t}^-$) is a vector that takes on the negative surprise in the target factor (or path factor) and a zero otherwise. Out of the 136 observations under consideration, there are 46 positive surprises in the federal funds target rate and 60 negative surprises in the federal funds target rate from the federal fund futures data.

4.2 Size response

The reaction of the foreign exchange market can be asymmetric, depending on the size of the surprises in monetary policy. Thus, we estimate the following regressions using SUR:

$$y_{i,t} = \alpha_0 + \beta_i^L f_t^L + \beta_i^S f_t^S + \theta_i S\,\&\,P^{net\ FOMC} + \varepsilon_{fi,t} \tag{8}$$

$$y_{i,t} = \alpha_1 + \gamma_i^L z_{1,t}^L + \gamma_i^S z_{1,t}^S + \lambda_i^L z_{2,t}^L + \lambda_i^S z_{2,t}^S + \theta_i S\,\&\,P^{net\ FOMC} + \varepsilon_{zi,t} \tag{9}$$

where f_t^L (f_t^S) is a vector that takes on the value of the large (small) surprises in the federal funds rate and a zero otherwise; $z_{1,t}^L$ ($z_{2,t}^L$) is a vector that takes on the value of the large target factor (path factor) and a zero otherwise; $z_{1,t}^S$ ($z_{2,t}^S$) is a vector that takes on the value of the small target factor (path factor) and a zero otherwise. A variable is defined as being large if it is greater than the median value of the absolute values of all observations for that variable. Christie-David, Chaudhry and Lindley (2003) used a similar specification to examine the asymmetric impact of macroeconomic news on bond prices and found that a large surprise has a bigger impact.

4.3 Direction of rate movement

The third type of asymmetry we examine is whether the impact of monetary policy surprises differs between expansionary or tightening periods of the monetary policy. Similar to the empirical model in Jensen, Mercer and Johnson (1996), we estimate the following regressions:

$$y_{i,t} = \alpha_0 + \beta_i^U f_t^U + \beta_i^D f_t^D + \theta_i S\,\&\,P^{net\,FOMC} + \varepsilon_{fi,t} \tag{10}$$

$$y_{i,t} = \alpha_1 + \gamma_i^U z_{1,t}^U + \gamma_i^D z_{1,t}^D + \lambda_i^U z_{2,t}^U + \lambda_i^D z_{2,t}^D + \theta_i S\,\&\,P^{net\,FOMC} + \varepsilon_{zi,t} \tag{11}$$

where f_t^U (f_t^D) is a vector that takes on the value of the positive (negative) changes in the federal funds rate and a zero otherwise; $z_{1,t}^U$ ($z_{1,t}^D$) is a vector that takes on the value of the target factor when the change in the federal funds rate is positive (negative) and a zero otherwise; and $z_{2,t}^U$ ($z_{2,t}^D$) is a vector that takes on the value of the path factor when the change in the federal funds rate is positive (negative) and a zero otherwise. Among the 136 observations in our sample, there are 19 observations with an increase in the federal funds target rate and 34 observations with a cut in the target rate.

4.4 Direction of the business cycle

We divide the sample into periods of economic expansion (from February 1990 to June 1990, from April 1991 until February 2001, and from December 2001 until present) and periods of economic recession (from July 1990 until March 1991 and from March 2001 until November

2001) based on the NBER business cycle dates. This definition is similar to that of Andersen, Bollerslev, Diebold and Vega (2003) and would give us 117 observations during the economic expansion and 19 observations during the economic recession. We then estimate the following regressions:

$$y_{i,t} = \alpha_0 + \beta_i^E f_t^E + \beta_i^R f_t^R + \theta_i S\,\&\,P^{net\,FOMC} + \varepsilon_{fi,t} \tag{12}$$

$$y_{i,t} = \alpha_1 + \gamma_i^E z_{1,t}^E + \gamma_i^R z_{1,t}^R + \lambda_i^E z_{2,t}^E + \lambda_i^R z_{2,t}^R + \theta_i S\,\&\,P^{net\,FOMC} + \varepsilon_{zi,t} \tag{13}$$

where f_t^E (or f_t^R) is a vector that takes on the value of the surprises in the federal funds rate when the economy is in an expansion (or recession) and a zero otherwise; $z_{1,t}^E$ (or $z_{1,t}^R$) is a vector that takes on the value of the surprises in the target factor when the economy is in an expansion (or recession) and a zero otherwise; and $z_{2,t}^E$ (or $z_{2,t}^R$) is a vector that takes on the value of the surprises in the path factor when the economy is in an expansion (recession) and a zero otherwise.

4.5 Persistence

Finally, to examine how quickly currency prices react to the monetary policy surprises, we use the same specifications as above but replace the dependent variable (the five-minute returns immediately after the policy changes) with different five-minute returns at different points in time after the news releases. Specifically, we consider the five-minute returns between the five- and the ten-minute marks and between the ten- and fifteen-minute marks. We also consider the 15-minute returns between the fifteen- and thirty-minute marks and between the thirty- and forty-five-minute marks after the policy changes. Hence, we can examine the return persistence by determining the length of time before returns are insignificantly different from zero in a continuous manner (with assurance of no confounding effect of other macroeconomic news).

5. Empirical results

5.1 Baseline regression

Table 1 presents the results of estimating the two empirical specifications described in equations (4) and (5). The purpose of estimating the two empirical specifications is to compare a one-factor empirical specification, equation (4), with a two-factor empirical specification, equations (5). In both sets of regressions the dependent variables are the currency futures' returns. The one-factor empirical specification regresses the currency futures' returns on the surprise component of the change in the federal funds target rate (FFR), while the two-factor empirical specification regresses the currency futures' returns on a factor that is related to the surprise in the federal funds target rate (Target) and on a factor that is related to the expected future path of rate changes (Path). Neither of the empirical specifications makes any attempt to address the possibility that reactions in the currency futures market can vary depending on the values of the independent variables. In other words, these baseline regressions implicitly assume that reactions are symmetrical.

In the context of the one-factor empirical specification in the preliminary analysis, responses of the currency futures' returns to a positive surprise in the FFR are all statistically significant and negative. Furthermore, the magnitudes of the responses appear to be similar for the three currency futures contacts, and a Wald test cannot reject the hypothesis that the three coefficients are equal.

When we examine the results for the two-factor empirical specification, however, we see that the coefficient on the target factor is not significant for the Euro, and is only significant at the 10% level for the Yen. Furthermore, a Wald test rejects the hypothesis that the three coefficients on the target factor for the three currency futures are equal.

The returns on the three currency futures all exhibit statistically significant, negative relations to the path factor. While the coefficients are all negative and statistically different than zero, a Wald test rejects the hypothesis that the three coefficients on the path factor for the three currency futures are equal to one another.

Model selection tests are conducted using the Akaike information criteria (AIC) to examine whether the one-factor or two-factor specification best fits the data. As presented in Tables 1-5, the AIC are, in most cases, smaller for the two-factor specification than for the one-factor specification. In other cases, the AIC for the two-factor empirical specification are at least no larger than for the one-factor specification. This suggests the two-factor empirical specification is, in most cases, better than, or at least as good as, the one-factor empirical specification. This conclusion is valid even after allowance is made for built-in penalties in AIC for the more explanatory variables in the two-factor empirical specifications.

We also assumed that target factor and federal funds rate surprises are not exactly the same, and thus conducted Davidson and MacKinnon's (1981) J-test, which is a model specification test for two non-nested econometric models. Again, the J-test statistic suggested that the two-factor specification is preferred over the one-factor specification for all the econometric models considered in this study.[11]

[11] We thank the referee for suggesting formal econometric model selection tests. Based on the baseline (asymmetric sign) regression, the J test statistics is 5.2 (5.98), which rejects the one-factor empirical specification at the 1% significance level and is in favor of the two-factor empirical specification. The results are similar for other asymmetric regressions. We could also assume that the target factor and the federal funds rate surprises are the same

5.2 Asymmetric response to sign of surprises

Table 2 presents results on asymmetric responses to the signs of surprises in monetary policy using five-minute returns data. In the one-factor empirical specification, uniformly across all three futures contracts, positive surprises in the FFR have a statistically significant, negative impact on the currency futures. Conversely, a negative surprise in the FFR has no statistically significant impact on currency futures prices except for the British Pound futures. This suggests that if the current target rate is adjusted upwards by more than was expected, the U.S. dollar tends to appreciate and the foreign currency depreciate. This is consistent with the asset-market approach to exchange rate determination, which considers that a higher domestic interest rate raises the return on the domestic assets, thus attracting capital inflow and appreciating the domestic currency. The results for the target factor in the two-factor specification are similar to those for the FFR in the one-factor specification. There is a similar pattern reported for the path factor: positive surprises in the path factor have statistically significant, negative impacts on currency futures prices, while negative surprises in the path factor have no statistically significant impacts.

The sign-related asymmetry reported here might be broadly consistent with that of Andersen, Bollerslev, Diebold and Vega (2003). As highlighted (p. 58), the key mechanism in Veronesi's (1999) model through which bad news in good times translates into large price movements, is increased uncertainty about the state of the economy. Since our data sample covers mostly the economy's expansion period, the positive surprise (i.e., unexpected rate increase) might be considered bad news. This could be a disproportionately important concern to

---

(as they are very highly correlated). In this case, the statistical significance of the path factor indicates the superiority of the two-factor empirical specification over the one-factor empirical specification.

risk-averse investors, thereby generating disproportionately high uncertainty regarding changes in the cost of capital and changes in investment portfolios in the U.S. economy. Nevertheless, Andersen, Bollerslev, Diebold and Vega (2003) implicitly assume dollar depreciation (or foreign currency appreciation) due to less favorable U.S. macroeconomic news as bad news on currency futures markets. In this context, dollar appreciation due to the positive surprise might also be considered good news, and thus good monetary policy news might have more pronounced instantaneous effects on currency futures market. In line with this argument, Wang, Yang and Wu (2006) also find that investors trading on U.S. stock index ETFs only react to the negative surprise (or unexpected decreases) in the target and path factors in the first five minutes after the announcements, which is clearly an indicator of good monetary policy news on the equity market.[12]

Quantitatively, for the two-factor specification, the contract values decrease by 0.17, 0.32 and 0.29%, respectively, with a 25-basis-point increase in the federal funds target rate surprise for the British Pound, Euro, and the Japanese Yen futures. For the path factor, the contract values decrease by roughly the same magnitude with a 25-basis-point surprise increase in the 4-quarter-ahead Eurodollar futures rate for the Pound, Euro, and the Yen futures. Therefore, currency futures react by roughly the same magnitude to the target and the path factors.

Wald tests reject the hypothesis that the coefficients for positive surprises in the FFR are equal to the coefficients for negative surprises in the FFR. Similar hypotheses are also rejected for positive and negative changes in the target factor and in the path factor.

[12] It would be interesting to further investigate such an intriguing empirical finding in future research. Here we only offer some preliminary thoughts. A plausible behavioral explanation might be that bad firm-specific news has more influence on investor behavior than good firm-specific news, because investors can feel stronger regret when the potential loss can be tied to their own decisions. However, if investors can attribute the loss to reasons that are out of their control, the feeling of regret could well be weaker. In such a case, seeking pride might take the place of avoiding regret, and investors might simply embrace good (rather than bad) macroeconomic news instantaneously.

5.3 Asymmetric response to size of surprises

Table 3 reports the results for when surprises are divided into those of large and small magnitude. Large surprises in the target factor tend to have a statistically significant, negative relation with changes in two out of three futures prices. Small surprises in the target factor tend to have a statistically insignificant impact on the foreign currency futures prices. Large surprises in the path factor also have statistically significant, negative impacts on all currency futures prices, while small shocks have statistically insignificant coefficients. Somewhat surprisingly, Wald tests on differences in these coefficients, across all three currencies, cannot reject the hypothesis that the coefficients of large versus small surprises are equal. Overall, in contrast to earlier studies (e.g., Christie-David, Chaudhry and Lindley, 2003), there is only moderate evidence supporting the view that larger shocks contain more substantial news content, and thus cause more significant adjustments to the exchange rate.

5.4 Asymmetric response depending on direction of rate change

We further examine whether the impacts of monetary policy surprises differ during periods of loosening or tightening monetary policy. The results in Table 4 suggest that surprises in the FFR and the target factor have a statistically significant impact on the returns of three currency futures during periods of monetary policy tightening. This result complements that of Table 2, where only positive surprises generally matter. Importantly, the evidence here confirms that of Lobo, Darrat and Ramchander (2006) in a more robust high frequency framework, with the exception of the Japanese Yen.

For the path factor, evidence of asymmetric impact is weaker; some currency futures display statistically significant impacts, mainly during periods of monetary contraction, but this is not true in all cases.

5.5 Asymmetric response depending on state of economy

Table 5 presents the results when the sample is bifurcated depending on the state of economy. When considering Table 5, it can be seen that monetary policy surprises have noticeable impacts on both the target and path factors during expansionary periods in the economy, when interest rates tend to increase. The impacts are not observed to the same degree during recessionary periods, when interest rates tend to decline. This occurs uniformly across all foreign exchange futures contracts and confirms results presented in Tables 2 and 4. Hence, it is confirmed that unexpected rate increases have the greatest impact on currency futures markets.[13]

5.6 Robustness check

Previous results indicate that for the three foreign exchange futures, both the current stance and the future direction of monetary policy have an impact on five-minute returns. It is worth noting, however, that during the early part of the sample, FOMC statements were not issued regarding the future direction of monetary policy. This presents an issue as to whether the use of the sample without FOMC statements is appropriate for the construction of the path factor. We examine the issue by removing those observations without FOMC statements, leaving only 59 observations after February 1994; results of these regressions are presented in Table 6. Little difference is observed; the signs of coefficients remain the same, and are generally of the same, if not greater magnitude as those reported for the previous regressions.[14]

---

[13] Following the referee's suggestion, we also conducted additional analysis to examine the impact of monetary policy surprises on currency futures volatility. The regression setup closely follows Balduzzi, Elton and Green (2001), Christie-David, Chaudhry and Lindley (2003), and Ederington and Lee (1993), among others. In particular, we regress the absolute values of currency futures returns on the absolute values of the target, path factors as well as $S\&P^{netFOMC}$. We confirm the impacts of both factors on currency futures volatility (particularly in the first five minutes), while the impact for the path factor is somewhat weaker than in the case of returns. Similar asymmetric effects of target and path factors on currency futures volatilities are also largely confirmed. The detailed results are available.

[14] The regression results for other specifications are similar and available.

The potential problem of influential observations is also considered. We use Hadi's (1994) method to identify outliers in a multivariate setting and find a total of three potential outliers at the one percent significance level. These outliers (dated December 20, 1991; January 3, 2001; and April 18, 2001) generally correspond to large numbers in the target and path factors, and therefore large surprises in rate changes. Results of sign regressions, excluding these outliers (available on request), demonstrate that the signs of the coefficients remain the same, and currency futures still respond to current and future rate increases. Coefficients for negative surprises in the target factor become statistically significant across all three currency futures, despite their smaller magnitude when compared with coefficients for positive surprises. The coefficients on negative surprises in the path factor are not statistically significant after removal of the outliers. Quantitatively, coefficients are similar in absolute values to those of previous regressions presented in Table 2.

Finally, the dummy variable approach, though widely adopted, might be inappropriate in this instance due to its failure to capture all potential asymmetry. Therefore, we undertook a more robust nonparametric kernel regression for both one- and two-factor specifications and compared the results with those reported in the tables. The best fit, measured by R-squared values, is always obtained for the nonparametric two-factor empirical specification across all three currencies. The R-squared value for the nonparametric two-factor specification is far higher than that of either of the models that do not account for asymmetry or the nonparametric one-factor specification, suggesting both the necessity of including the two factors and the existence of asymmetry. This finding is particularly relevant for the British Pound and Euro.

5.7 Persistence

Panel A of Table 7 presents the return persistence regression results using specifications from equations (4) and (5). For the target factor, estimated coefficients are statistically negative mainly within the first 10 minutes of policy changes. This result is consistent with the majority of studies considering macroeconomic news announcements and their impact on asset prices, which generally lasts around 10 to 15 minutes (Ederington and Lee, 1993; Balduzzi, Elton and Green, 2001). For the path factor, estimated coefficients are negative and statistically significant within the first five minutes of policy changes; they become statistically insignificant after 30 minutes.

Panel B of Table 7 presents a robustness check; the return persistence results based on the alternative specification with the sign response dummies. The result is generally consistent with the first five-minute results on signs regression; that is, surprise increases in the federal funds target rate have more significant impacts on currency futures up to the fifteen-minute mark. The impact of the path factor is similar to that of the target factor, with positive surprises in the path factor having statistically significant negative impacts, although these do not last. Panel C of Table 7 presents the persistence results based on the state-of-the-economy regressions. The results are similar to that of the five-minute returns regression: for both the target factor and the path factor, monetary policy changes seem to be mostly effective during expansionary periods of the business cycle.

Overall, the persistence results demonstrate that the impact of monetary policy surprises mainly last up to the ten-minute mark, suggesting currency markets rapidly digest new information.

Cumulative reaction coefficients for all three currencies, responding to changes in target and path factors, suggest that whenever there are positive surprises in either the current federal funds rate or in the anticipated path of future federal funds rates, investors entering into positions immediately after the announcement could "short" these three currency futures. This suggests that profit potential might exist within forty-five minutes of an announcement.

However, it would be risky to enter into positions if the market clears very quickly and prices jump without a great deal of trading (Fleming and Remolona, 1999). We also considered a simple trading rule that an investor should go long in currency futures when both target and path factors are negative, and should short currency futures when both target and path factors are positive.[15] The results (available on request) demonstrate average returns per trade of 0.07, 0.10 and 0.05% for the Pound, Euro, and Yen, respectively; this is without allowance for transaction costs. These results are valid for investors entering into positions immediately after the FOMC announcement and holding the position for forty-five minutes. However, the numbers are not statistically significant, and therefore the trading rule remains risky.

6. Conclusions

In this study we use intraday data to assess the impact of monetary policy surprises on three major currency futures: the British Pound, the Deutsche Mark/Euro, and the Japanese Yen. We find that policy surprises in both the current federal funds target rate and the path of expected future funds rate changes impact the foreign currency futures. Our study further considers the potentially asymmetric reaction of these markets depending on the sign and size of the monetary policy surprises. We also investigate asymmetries related to whether there is a concurrent loosening or a tightening of monetary policy and on whether the economy is in a contractionary or an expansionary phase of the business cycle.

---

[15] Investors might not know the exact values for the target and path factors right after the meetings, but by checking the federal funds futures and the Eurodollar futures price movements, investors would likely be able to tell whether the surprises are positive or negative.

We find that: 1) a two-factor empirical specification, which includes both a target factor and a path factor, is generally better than the one-factor empirical specification, which only considers changes in the federal fund rate surprise, at explaining the currency futures returns following monetary policy announcements;[16] 2) the currency futures prices respond to positive surprises but have little or no response to negative surprises in the monetary policy variables; 3) rate surprises during times of monetary tightening have an impact on the currency futures returns but not during monetary expansions; and 4) during economic expansions, changes in the monetary variables lead to significant price changes in currency futures while rate surprises during times of recession tend to have no significant impact on the currency futures markets. In addition, we perform a number of tests that demonstrate the robustness of the analyses.

The overall results presented in this paper are consistent with the asset-market-based approach to exchange rate determination, which postulates that higher interest rates lead to an appreciation of the domestic currency. A possible avenue for future research is an examination of whether the reported, high-frequency, asymmetric patterns are not only applicable to the British Pound, Euro, and Japanese Yen but also to other currencies and other financial markets.

[16] The finding stands in contrast to little evidence of the path factor on the US stock market (e.g., Gurkaynak, Sack and Swanson, 2005), but is consistent with Wang, Yang, and Wu (2006). More importantly, the result here suggests that surprises in both the current and future rate changes have an impact with similar significance on the currency futures markets, which has not been reported previously.

References

Almeida, A., C. Goodhart and R. Payne, 1998. The effects of macroeconomic news on high frequency exchange rate behavior, *Journal of Financial and Quantitative Analysis* 33, 383-406.

Andersen, T., T. Bollerslev, F.X. Diebold and C. Vega, 2003. Micro effects of macro announcements: Real-time price discovery in foreign exchange, *American Economic Review* 93, 38-62.

Andersen, T., T. Bollerslev, F.X. Diebold and C. Vega, 2007. Real-time price discovery in stock, bond and foreign exchange markets, *Journal of International Economics* 73, 251-277.

Balduzzi, P., E.J. Elton and T.C. Green, 2001. Economic news and bond prices: Evidence from the U.S. treasury market, *Journal of Financial and Quantitative Analysis* 36, 523-43.

Barberis, N., A. Shleifer and R. Vishny, 1998. A model of investor sentiment, *Journal of Financial Economics* 49, 307-348.

Bernanke, B.S. and K.N. Kuttner, 2005. What explains the stock market's reaction to federal reserve policy? *Journal of Finance* 60, 1221-1257.

Bernanke, B.S., V. Reinhart and B. Sack, 2004. Monetary policy alternatives at the zero bound: An empirical assessment, Finance and Economics Discussion Series 2004-48, The Federal Reserve Board.

Bonser-Neal, C., V.V. Roley and G.H. Sellon, 2000. The effect of monetary policy actions on exchange rates under interest-rate targeting, *Journal of International Money and Finance* 19, 601-631.

Christie-David, R., M. Chaudhry and J.T. Lindley, 2003. The effects of unanticipated macroeconomic news on debt markets, *Journal of Financial Research* 26, 2003, 319-339.

Conrad, J.S., B. Cornell and W.R. Landsman, 2002. When is bad news really bad news? *Journal of Finance* 57, 2507-2532.

Davidson, R. and J. MacKinnon, 1981. Several tests for model specification in the presence of alternative hypotheses, *Econometrica* 49, 781-793.

Ederington, L.H. and J.H. Lee, 1993. How markets process information: News releases and volatility, *Journal of Finance* 48, 1161-1191.

Eichenbaum, M. and C. Evans, 1995. Some empirical evidence on the effects of shocks to monetary policy on exchange rates, *Quarterly Journal of Economics* 110, 975-1009.

Faust, J., J.H. Rogers, S.B. Wang and J.H. Wright, 2007. The high-frequency response of exchange rates and interest rates to macroeconomic announcements, *Journal of Monetary Economics* 54, 1051-1068.

Fleming, M.J. and E.M. Remolona, 1999. Price Formation and Liquidity in the U.S. Treasury Market: The Response to Public Information, *Journal of Finance* 54, 1901-1915.

Gurkaynak, R.S., B.P. Sack and E.T. Swanson, 2005. Do actions speak louder than words? The response of asset prices to monetary policy actions and statements, *International Journal of Central Banking* 1 (1), 55-93.

Hadi, A.S., 1994. A modification of a method for the detection of outliers in multivariate samples, *Journal of the Royal Statistical Society (Series B)* 56, 393-396.

Hausman, J. and J. Wongswan, 2006. Global Asset Prices and FOMC Announcements International Finance Discussion Papers 2006-886, The Federal Reserve Board.

Haynes, S.E., 1983. The subtle danger of symmetry restrictions in time series regressions: With application to fertility models, *Southern Economic Journal* 50, 521-528.

Johnston, J., 1972. Econometric Methods, 2nd Edition. (McGraw-Hill, New York.)

Jensen, G., J.M. Mercer and R.R. Johnson, 1996. Business conditions, monetary policy, and expected security returns, *Journal of Financial Economics* 40, 213-237.

Jansen, D.J. and J. De Haan, 2005. Talking heads: The effects of ECB statements on the euro-dollar exchange rate, *Journal of International Money and Finance* 24, 343-361.

Kohn, D.L. and B.P. Sack, 2003. Central bank talk: Does it matter and why? Working paper, Federal Reserve Board.

Kuttner, K.N., 2001. Monetary policy surprises and interest rate: Evidence from the Fed Funds futures market, *Journal of Monetary Economics* 47, 523-544.

Lobo, B.J., A.F. Darrat and S. Ramchander, 2006. The asymmetric impact of monetary policy on currency markets, *The Financial Review* 41, 289-303.

Pakko, M.R., 2005. On the information content of asymmetric FOMC policy statements: Evidence from a Taylor-rule perspective, *Economic Inquiry* 43, 558-69.

Rigobon, R. and B.P. Sack, 2004. The impact of monetary policy on asset prices, *Journal of Monetary Economics* 51, 1553-75.

Rudebusch, G.D., 1998. Do measures of monetary policy in a VAR make sense? *International Economic Review* 39, 907-931.

Simpson, M.W., S. Ramchander and J. Webb, 2007. The Asymmetric Response of Equity REIT Returns to Inflation, *Journal of Real Estate Finance and Economics* 34, 513-529.

Wang, T., J. Yang and J. Wu, 2006. Central Bank Communications and Equity ETFs, *Journal of Futures Markets* 26, 959-995.

Veronesi, P., 1999. Stock market overreaction to bad news in good times: A rational expectations equilibrium model, *Review of Financial Studies* 12, 975-1007.

White, H., 1980. A heteroscedasticity-consistent covariance matrix estimator and a direct test for heteroscedasticity, *Econometrica* 48, 817-838.

Wongswan, J., 2005. The response of global equity indexes to U.S. monetary policy announcements. International Finance Discussion Papers 844, Washington: Board of Governors of the Federal Reserve System.

Wongswan, J., 2006. Transmission of information across international equity markets, *Review of Financial Studies* 19, 1157-1189.

Table 1

Baseline regression

	One-factor empirical specification			*Two-factor empirical specification*		
	Pound	Euro	Yen	Pound	Euro	Yen
Surprise in FFR	-0.0421	-0.0331	-0.0326			
	(-3.63)***	(-1.98)**	(-2.78)***			
Target				-0.0364	-0.0222	-0.0215
				(-3.07)***	(-1.31)	(1.76)*
Path				-0.032	-0.0466	-0.0262
				(-3.58)***	(-3.65)***	(-2.85)***
$S\&P^{Net\ FOMC}$	-0.0886	-0.145	-0.0078	-0.0896	-0.1458	-0.0085
	(3.09)***	(-3.51)***	(-0.27)	(-3.21)***	(-3.66)***	(-0.3)
Constant	-0.0071	0.0249	-0.0227	0.0835	0.0955	0.0455
	(-0.0700)	(0.1700)	(-0.22)	(0.86)	(0.69)	(0.46)
R2	0.1442	0.1074	0.0542	0.1902	0.1719	0.0751
# of observations	136	136	136	136	136	136
Hypotheses:						
Coeffs. for FFR surprise are equal		1.6933				
P-value		0.4288				
Coeffs. for path surprise are equal					6.2685	
P-value					0.0435	
Coeffs. for target and path surprise are equal					10.1679	
P-value					0.0377	
Specification test:						
All coefficients (except the constant) are zero		18.3870			28.388	
P-value		0.0004			0.0001	
Akaike Information Criteria (AIC)		1107			1103	

Notes:

1. t- statistics based on White's (1980) robust standard errors (in parentheses)
2. *, ** and *** indicate statistical significance at 10%, 5% and 1%, respectively
3. FFR: Federal funds rate derived from the federal funds futures
4. Sample period is from February 1990 to December 2004

Table 2

Asymmetric sign response

	One-factor empirical specification			*Two-factor empirical specification*		
	Pound	Euro	Yen	Pound	Euro	Yen
Positive surprise in FFR	-0.1085	-0.1487	-0.1161			
	(-3.42)***	(-3.28)***	(-3.65)***			
Negative surprise in FFR	-0.0239	-0.0013	-0.0096			
	(-1.71)*	(-0.07)	(-0.69)			
Positive target				-0.0687	-0.1290	-0.1169
				(-1.98)**	(-2.63)***	(-3.36)***
Negative target				-0.0319	0.0059	0.0031
				(-2.05)**	(0.27)	(0.20)
Positive path				-0.0609	-0.0747	-0.0535
				(-4.03)***	(-3.48)***	(-3.52)***
Negative path				-0.0075	-0.0282	-0.0077
				(-0.51)	(-1.37)	(-0.53)
S&P$^{Net\ FOMC}$	-0.0700	-0.1126	0.0156	-0.0810	-0.1160	0.0180
	(-2.38)**	(-2.68)***	(0.53)	(-2.81)***	(-2.84)***	(0.62)
Constant	0.1575	0.3115	0.1842	0.3736	0.6172	0.5257
	(1.27)	(1.76)*	(1.48)	(2.28)**	(2.65)***	(3.19)***
R2	0.1747	0.1539	0.1063	0.2259	0.2158	0.1546
# of observations	136	136	136	136	136	136
Hypotheses:						
Coeffs. for pos. and neg. FFR surprise are equal		8.9297				
P-value		0.0302				
Coeffs. for pos. and neg. path are equal					6.4720	
P-value					0.0908	
Coeffs. for pos. and neg. target and path are equal					20.2972	
P-value					0.0025	
Specification test:						
All coefficients (except the constant) are zero		27.6265			50.0230	
P-value		0.0001			0.0000	
Akaike Information Criteria (AIC)		1104			1096	

Notes:

1. t- statistics based on White's (1980) robust standard errors (in parentheses)

2. *, ** and *** indicate statistical significance at 10%, 5% and 1%, respectively

Table 3

Size response

	One-factor empirical specification			*Two-factor empirical specification*		
	Pound	Euro	Yen	Pound	Euro	Yen
Large shock in FFR	-0.0414	-0.0322	-0.0313			
	(-3.56)***	(-1.92)*	(-2.67)***			
Small shock in FFR	-0.1269	-0.1369	-0.1743			
	(-0.96)	(-0.72)	(-1.31)			
Target*dummy (FFR-Large)				-0.0448	-0.0280	-0.0284
				(-3.68)***	(-1.59)	(-2.26)**
Target*dummy (FFR-Small)				0.0752	0.0309	0.0529
				(1.24)	(0.35)	(0.85)
Large shock in path				-0.0321	-0.0484	-0.0274
				(-3.59)***	(-3.75)***	(-2.97)***
Small shock in path				0.0505	0.0615	0.0753
				(0.90)	(0.76)	(1.30)
$S\&P^{Net\ FOMC}$	-0.0888	-0.1452	-0.0081	-0.0897	-0.1461	-0.0088
	(-3.10)***	(-3.52)***	(-0.28)	(-3.28)***	(-3.70)***	(-0.31)
Constant	-0.0030	0.0300	-0.0158	-0.0648	0.0143	-0.0606
	(-0.03)	(0.20)	(-0.15)	(-0.54)	(0.08)	(-0.49)
R2	0.1468	0.1094	0.0621	0.2235	0.1853	0.1059
# of observations	136	136	136	136	136	136
Hypotheses:						
Coeffs. for L and S FFR surprise are equal		1.3314				
P-value		0.7217				
Coeffs. for L and S path are equal					3.1776	
P-value					0.3650	
Coeffs. for L and S target and path are equal					10.1617	
P-value					0.1180	
Specification test:						
All coefficients (except the constant) are zero		19.8036			39.7660	
P-value		0.0030			0.0001	
Akaike Information Criteria (AIC)		1112			1106	

Notes:

1. t- statistics based on White's (1980) robust standard errors (in parentheses)

2. *, ** and *** indicate statistical significance at 10%, 5% and 1%, respectively

Table 4

Direction of rate movement

	One-factor empirical specification			*Two-factor empirical specification*		
	Pound	Euro	Yen	Pound	Euro	Yen
FFR surprise*dummy (rate increase)	-0.1445	-0.2027	-0.1025			
	(-4.09)***	(-4.03)***	(-2.79)***			
FFR surprise*dummy (rate decrease)	-0.0285	-0.0055	-0.0127			
	(-2.16)**	(-0.29)	(-0.92)			
Target*dummy (rate increase)				-0.1519	-0.1883	-0.1153
				(-3.59)***	(-3.16)***	(-2.63)***
Target*dummy (rate decrease)				-0.0264	0.0035	-0.0019
				(-1.90)*	(0.18)	(-0.13)
Path*dummy (rate increase)				-0.0533	-0.0955	-0.0500
				(-1.98)**	(-2.52)**	(-1.79)*
Path*dummy (rate decrease)				-0.0240	-0.0502	-0.0256
				(-1.45)	(-2.15)**	(-1.49)
$S\&P^{Net\ FOMC}$	-0.0706	-0.1104	0.0068	-0.0653	-0.1038	0.0154
	(-2.45)**	(-2.69)***	(0.23)	(-2.20)**	(-2.48)**	(0.50)
Constant	0.0904	0.1873	0.0675	0.1181	0.1864	0.0964
	(0.88)	(1.28)	(0.63)	(1.15)	(1.28)	(0.90)
R2	0.1973	0.1819	0.0636	0.2200	0.2203	0.0970
# of observations	136	136	136	136	136	136
Hypotheses:						
Coeffs. for FFR surprise are equal for increasing and declining rates		13.3615				
P-value		0.0039				
Coeffs. for path are equal for increasing and declining rates					1.0344	
P-value					0.7929	
Coeffs. For target and path are equal for increasing and declining rates					11.4931	
P-value					0.0743	
Specification test:						
All coefficients (except the constant) are zero		31.8050			42.6716	
P-value		0.0000			0.0000	
Akaike Information Criteria (AIC)		1102			1102	

Notes:

1. t- statistics based on White's (1980) robust standard errors (in parentheses)

2. *, ** and *** indicate statistical significance at 10%, 5% and 1%, respectively

Table 5

Direction of market movement

	One-factor empirical specification			*Two-factor empirical specification*		
	Pound	Euro	Yen	Pound	Euro	Yen
FFR surprise*dummy(expansion)	-0.0556	-0.0468	-0.0531			
	(-4.18)***	(-2.42)**	(-4.01)***			
FFR surprise*dummy(recession)	-0.0044	0.0058	0.0228			
	(-0.20)	(0.18)	(1.06)			
Target*dummy(expansion)				-0.0604	-0.0511	-0.0566
				(-4.32)***	(-2.55)**	(-3.98)***
Target*dummy(recession)				-0.0068	0.0094	0.0416
				(-0.33)	(0.32)	(1.98)**
Path*dummy(expansion)				-0.0408	-0.0586	-0.0324
				(-4.62)***	(-4.62)***	(-3.61)***
Path*dummy(recession)				0.0601	0.0900	0.0039
				(1.55)	(1.62)	(0.10)
$S\&P^{Net\ FOMC}$	-0.0841	-0.1402	-0.0008	-0.0877	-0.1456	0.0029
	(-2.96)***	(-3.41)***	(-0.03)	(-3.26)***	(-3.77)***	(0.10)
Constant	0.0057	0.0390	-0.0029	0.1621	0.1992	0.1241
	(0.06)	(0.27)	(-0.03)	(1.72)*	(1.47)	(1.29)
R2	0.168	0.120	0.114	0.270	0.243	0.183
# of observations	136	136	136	136	136	136
Hypotheses:						
Coeffs. for FFR surprise are equal for both periods		13.3615				
P-value		0.0039				
Coeffs. for path are equal for both periods					10.6281	
P-value					0.0139	
Coeffs. for target and path are equal for both periods					29.5037	
P-value					0.0000	
Specification test:						
All coefficients (except the constant) are zero		31.1000			61.1825	
P-value		0.0000			0.0000	
Akaike Information Criteria (AIC)		1102			1087	

Notes:

1. t- statistics based on White's (1980) robust standard errors (in parentheses)

2. *, ** and *** indicate statistical significance at 10%, 5% and 1%, respectively

Table 6

Asymmetric sign response with FOMC-statement samples only

	One-factor empirical specification			*Two-factor empirical specification*		
	Pound	Euro	Yen	Pound	Euro	Yen
Positive surprise in FFR	-0.1589	-0.2176	-0.1500			
	(-4.05)***	(-3.53)***	(-3.90)***			
Negative surprise in FFR	0.0218	0.0739	0.0413			
	(1.06)	(2.29)**	(2.06)**			
Positive target				-0.1060	-0.1599	-0.1548
				(-2.48)**	(-2.45)**	(-3.95)***
Negative target				0.0103	0.0628	0.0532
				(0.49)	(1.95)*	(2.74)***
Positive path				-0.0660	-0.0909	-0.0568
				(-3.58)***	(-3.23)***	(-3.36)***
Negative path				0.0060	-0.0094	0.0023
				(0.35)	(-0.36)	(0.15)
$S\&P^{Net\ FOMC}$	-0.0461	-0.0767	0.0330	-0.0686	-0.1042	0.0304
	(-1.28)	(-1.36)	(0.94)	(-1.97)**	(-1.96)*	(0.95)
Constant	0.3599	0.6592	0.3578	0.6703	1.0032	0.8227
	(1.87)*	(2.18)**	(1.90)*	(2.36)**	(2.31)**	(3.16)***
R2	0.288	0.292	0.215	0.303	0.342	0.324
# of observations	59	59	59	59	59	59
Hypotheses:						
Coeffs. for pos. and neg. FFR surprise are equal		17.2661				
P-value		0.0006				
Coeffs. for pos. and neg. path are equal					6.3989	
P-value					0.0937	
Coeffs. for pos. and neg. target and path are equal					24.8585	
P-value					0.0004	
Specification test:						
All coefficients (except the constant) are zero		24.3759			39.8510	
P-value		0.0004			0.0001	
Akaike Information Criteria (AIC)		512			512	

Notes:

1. t- statistics based on White's (1980) robust standard errors (in parentheses)

2. *, ** and *** indicate statistical significance at 10%, 5% and 1%, respectively

3. FFR: Federal funds rate derived from the federal funds futures

4. The sample is from May 1995 to December 2004. Observations without FOMC statements are dropped from the sample. The sample has 59 observations.

Table 7

Return persistence

Panel A: *Return persistence using the baseline two-factor empirical specification*

	0-5 minutes			5-10 minutes			10-15 minutes			15-30 minutes			30-45 minutes		
	Pound	Euro	Yen	Pound	Euro	Yen	Pound	Euro	Yen	Pound	Euro	Yen	Pound	Euro	Yen
Target	-0.0364	-0.0222	-0.0215	-0.0202	-0.0289	-0.0121	0.0015	-0.0193	-0.0150	-0.0058	0.0007	-0.0077	-0.0316	-0.0413	-0.0244
	(-3.07)***	(-1.31)	(-1.76)*	(-2.20)**	(-2.13)**	(-1.26)	(0.17)	(-1.60)	(-2.05)**	(-0.44)	(0.04)	(-0.61)	(-2.78)***	(-2.90)***	(-2.15)**
Path	-0.0320	-0.0466	-0.0262	-0.0099	-0.0087	-0.0070	-0.0005	-0.0014	0.0051	-0.0269	-0.0298	-0.0079	-0.0025	-0.0108	0.0009
	(-3.58)***	(-3.65)***	(-2.85)***	(-1.44)	(-0.85)	(-0.97)	(-0.08)	(-0.16)	(0.92)	(-2.66)***	(-2.09)**	(-0.84)	(-0.30)	(-1.00)	(0.10)
$S\&P^{Net\ FOMC}$	-0.0896	-0.1458	-0.0085	-0.0153	-0.0101	-0.0686	-0.0368	-0.0277	0.0123	-0.0252	-0.0287	0.0875	-0.0191	-0.0232	-0.0012
	(-3.21)***	(-3.66)***	(-0.30)	(-0.71)	(-0.32)	(-3.05)***	(-1.82)*	(-0.98)	(0.72)	(-0.80)	(-0.65)	(2.97)***	(-0.71)	(-0.69)	(-0.05)
R2	0.191	0.172	0.075	0.051	0.037	0.080	0.024	0.025	0.040	0.055	0.034	0.068	0.057	0.067	0.033
Observations	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136
Hypothesis															
Target Coeff. Eq.	3.8374			2.5636			11.0367			0.4358			2.6737		
P-value	0.0435			0.9180			0.0141			0.0936			0.2627		
Path Coeff. Eq.	6.2685			0.1711			1.3618			4.7382			2.5695		
P-value	0.1468			0.2775			0.0040			0.2661			0.2767		
Both Eq.	10.1679			2.7191			12.4893			5.2133			5.1098		
P-value	0.0377			0.6059			0.5062			0.8042			0.2762		

Panel B: *Return persistence using the sign response two-factor empirical specification*

	0-5 minutes			5-10 minutes			10-15 minutes			15-30 minutes			30-45 minutes		
	Pound	Euro	Yen	Pound	Euro	Yen	Pound	Euro	Yen	Pound	Euro	Yen	Pound	Euro	Yen
Positive target	-0.0687	-0.1290	-0.1169	-0.0175	0.0102	0.0333	-0.0170	-0.0843	-0.0471	0.0451	0.0889	-0.0188	-0.0517	-0.0299	-0.0061
	(1.98)**	(2.63)***	(3.36)***	(0.64)	(0.25)	(1.18)	(0.68)	(2.42)**	(2.18)**	(1.13)	(1.59)	(0.50)	(1.53)	(0.71)	(0.18)
Negative target	-0.0319	0.0059	0.0031	-0.0219	-0.0416	-0.0279	0.0040	-0.0042	-0.0056	-0.0235	-0.0257	-0.0032	-0.0259	-0.0458	-0.0278
	(2.05)**	(0.27)	(0.20)	(1.78)*	(2.30)**	(2.21)**	(0.35)	(0.27)	(0.58)	(1.31)	(1.02)	(0.19)	(1.70)*	(2.40)**	(1.83)*
Positive path	-0.0609	-0.0747	-0.0535	-0.0147	-0.0110	-0.0153	-0.0175	-0.0286	0.0014	-0.0353	-0.0232	-0.0030	-0.0058	-0.0159	0.0131
	(4.03)***	(3.48)***	(3.52)***	(1.23)	(0.63)	(1.25)	(1.59)	(1.88)*	(0.15)	(2.04)**	(0.95)	(0.18)	(0.40)	(0.86)	(0.89)

Negative path	-0.0075	-0.0282	-0.0077	-0.0053	-0.0036	0.0041	0.0139	0.0191	0.0062	-0.0153	-0.0295	-0.0133	-0.0010	-0.0051	-0.0092
	(0.51)	(1.37)	(0.53)	(0.46)	(0.21)	(0.35)	(1.31)	(1.30)	(0.68)	(0.92)	(1.26)	(0.85)	(0.07)	(0.29)	(0.65)
$S\&P^{Net\ FOMC}$	-0.0810	-0.1160	0.0180	-0.0162	-0.0212	-0.0815	-0.0318	-0.0098	0.0213	-0.0398	-0.0536	0.0908	-0.0134	-0.0265	-0.0062
	(2.81)***	(2.84)***	(0.62)	(0.71)	(0.63)	(3.49)***	(1.52)	(0.34)	(1.19)	(1.20)	(1.15)	(2.92)***	(0.48)	(0.75)	(0.22)
R2	0.226	0.216	0.155	0.052	0.045	0.105	0.053	0.082	0.058	0.070	0.054	0.069	0.061	0.068	0.043
Observations	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136
Hypothesis															
Coeffs. (pos. target = neg.)	13.2390			4.0694			5.5614			5.7324			2.7249		
P-value	0.0908			0.2541			0.1350			0.3674			0.4360		
Coeffs. (pos. path = neg.)	6.4720			1.3772			6.4837			3.1611			2.8194		
P-value	0.0041			0.7109			0.0903			0.1254			0.4203		

Panel C: *Return persistence using the direction of market movement two-factor empirical specification*

		0-5 minutes			5-10 minutes			10-15 minutes			15-30 minutes			30-45 minutes	
	Pound	Euro	Yen	Pound	Euro	Yen	Pound	Euro	Yen	Pound	Euro	Yen	Pound	Euro	Yen
Expansionary period*target	-0.0604	-0.0511	-0.0566	-0.0346	-0.0493	0.0030	0.0059	-0.0076	-0.0098	0.0054	0.0288	-0.0287	-0.0301	-0.0283	-0.0369
	(4.32)***	(2.55)**	(3.98)***	(3.10)***	(2.99)***	(0.26)	(0.56)	(0.52)	(1.09)	(0.33)	(1.24)	(1.88)*	(2.14)**	(1.62)	(2.65)***
Recession period*target	-0.0068	0.0094	0.0416	0.0047	0.0030	-0.0509	0.0017	-0.0242	-0.0189	-0.0348	-0.0591	0.0348	-0.0389	-0.0773	-0.0011
	(0.33)	(0.32)	(1.98)**	(0.29)	(0.12)	(2.99)***	(0.11)	(1.12)	(1.43)	(1.42)	(1.72)*	(1.54)	(1.87)*	(3.00)***	(0.05)
Expansionary period*path	-0.0408	-0.0586	-0.0324	-0.0134	-0.0144	-0.0078	0.0026	0.0064	0.0076	-0.0255	-0.0260	-0.0098	-0.0035	-0.0108	0.0005
	(4.62)***	(4.62)***	(3.61)***	(1.91)*	(1.38)	(1.07)	(0.40)	(0.70)	(1.35)	(2.44)**	(1.78)*	(1.02)	(0.39)	(0.98)	(0.05)
Recession period*path	0.0601	0.0900	0.0039	0.0025	0.0312	0.0476	-0.0521	-0.0970	-0.0306	0.0335	0.0146	-0.0114	0.0244	0.0660	0.0220
	(1.55)	(1.62)	(0.10)	(0.08)	(0.68)	(1.50)	(1.80)*	(2.41)**	(1.23)	(0.73)	(0.23)	(0.27)	(0.63)	(1.37)	(0.57)
$S\&P^{Net\ FOMC}$	-0.0877	-0.1456	0.0029	-0.0108	-0.0056	-0.0788	-0.0341	-0.0238	0.0133	-0.0336	-0.0422	0.0962	-0.0217	-0.0339	0.0022
	(3.26)***	(3.77)***	(0.10)	(0.50)	(0.18)	(3.56)***	(1.69)*	(0.85)	(0.77)	(1.05)	(0.95)	(3.28)***	(0.80)	(1.01)	(0.08)
R2	0.270	0.243	0.183	0.087	0.074	0.131	0.051	0.077	0.062	0.062	0.060	0.104	0.060	0.089	0.052
Observations	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136
Hypothesis															
Coeffs. exp = rec target	18.1374			33.3103			0.6868			28.7436			15.8985		
P-value	0.0139			0.0000			0.8763			0.4093			0.0012		
Coeffs. exp = rec target	10.6281			3.1099			6.3727			2.8875			3.7258		
P-value	0.0004			0.3750			0.0948			0.0000			0.2926		

Notes:

1. t- statistics based on White's (1980) robust standard errors (in parentheses)

2. *, ** and *** indicate statistical significance at 10%, 5% and 1%, respectively